

The Underlying Event from Tevatron to LHC



P. Skands (CERN)

Standard Model Benchmarks at the Tevatron and LHC, Fermilab, Nov 19-20, 2010

Min-Bias and UE

Minimum-Bias

High-Statistics reference laboratory

Study fragmentation:

Compare to ee!

Study hadron collisions:

Scaling

Soft-QCD

High Multiplicity

Diffraction

...

No hard scale → *all* observables depend significantly on IR physics

10-20% precision is *very good*

Min-Bias and UE

Minimum-Bias

High-Statistics reference laboratory

Study fragmentation:

Compare to ee!

Study hadron collisions:

Scaling

Soft-QCD

High Multiplicity

Diffraction

...

No hard scale → *all* observables depend significantly on IR physics
10-20% precision is *very good*

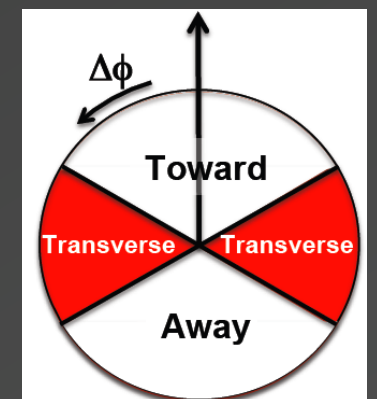
Underlying Event

Pedestal effect → larger than min-bias

Multiple parton interactions → multiple (mini)jets

Large fluctuations

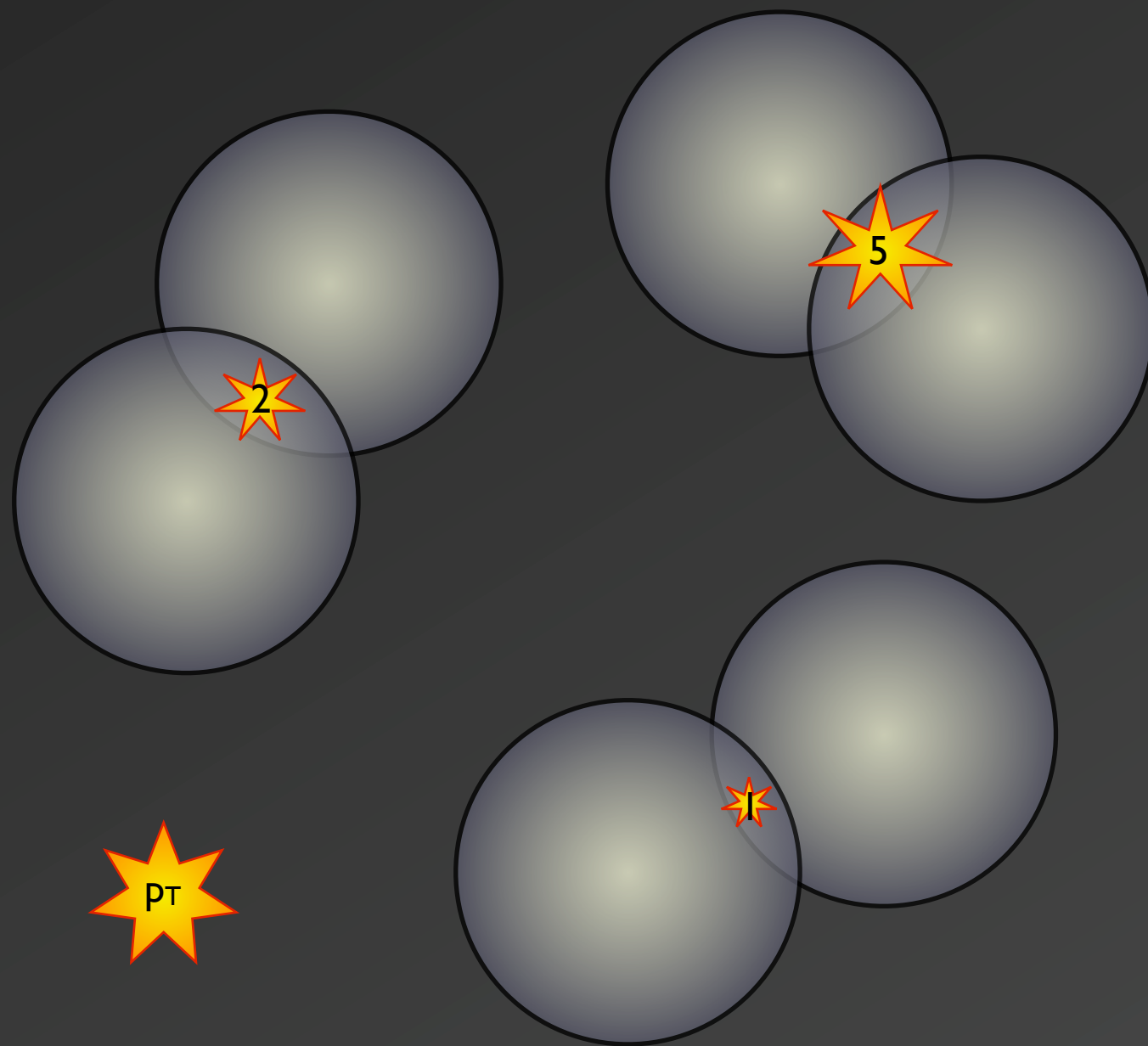
Hard scale present, but look at observables that don't (explicitly) involve it
10-20% precision is *very good*



The Pedestal Effect

and Multiple Parton-Parton Interactions

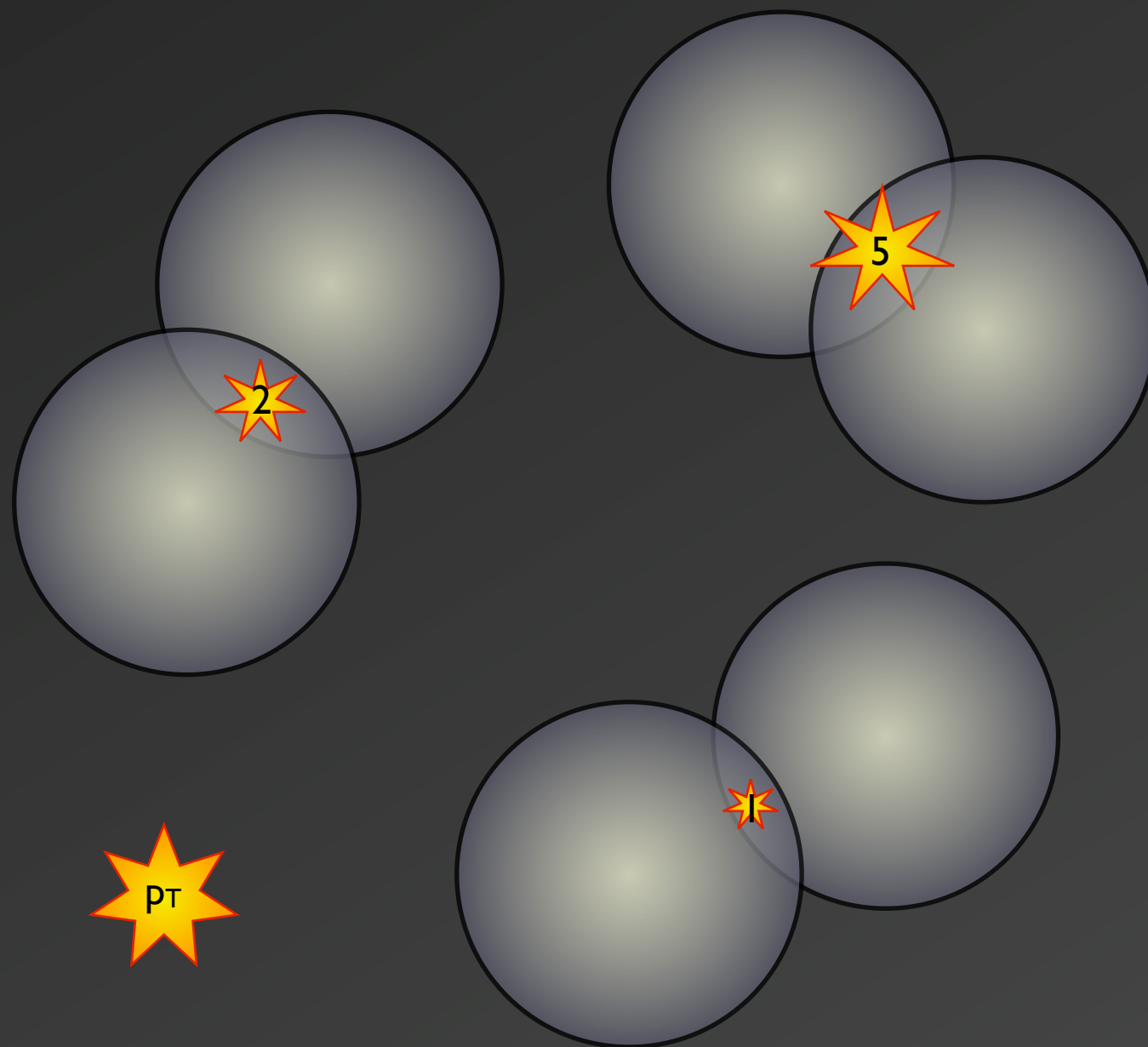
MINIMUM BIAS



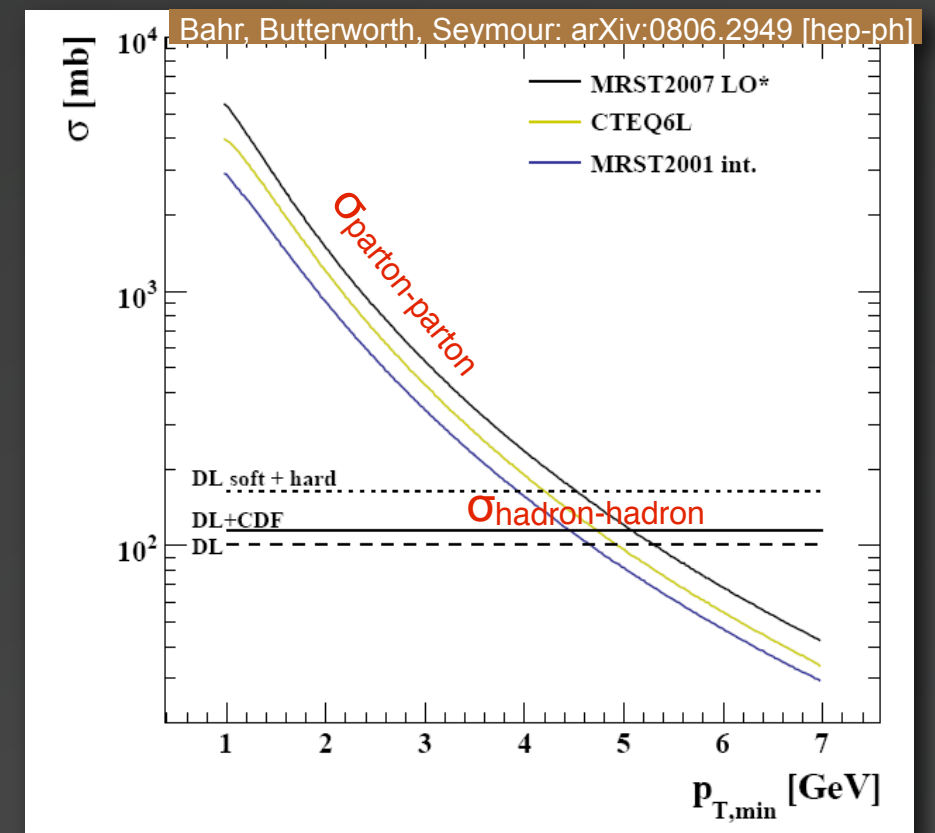
The Pedestal Effect

and Multiple Parton-Parton Interactions

MINIMUM BIAS



$\sigma_{\text{parton-parton}}$
 $> \sigma_{\text{hadron-hadron}}$

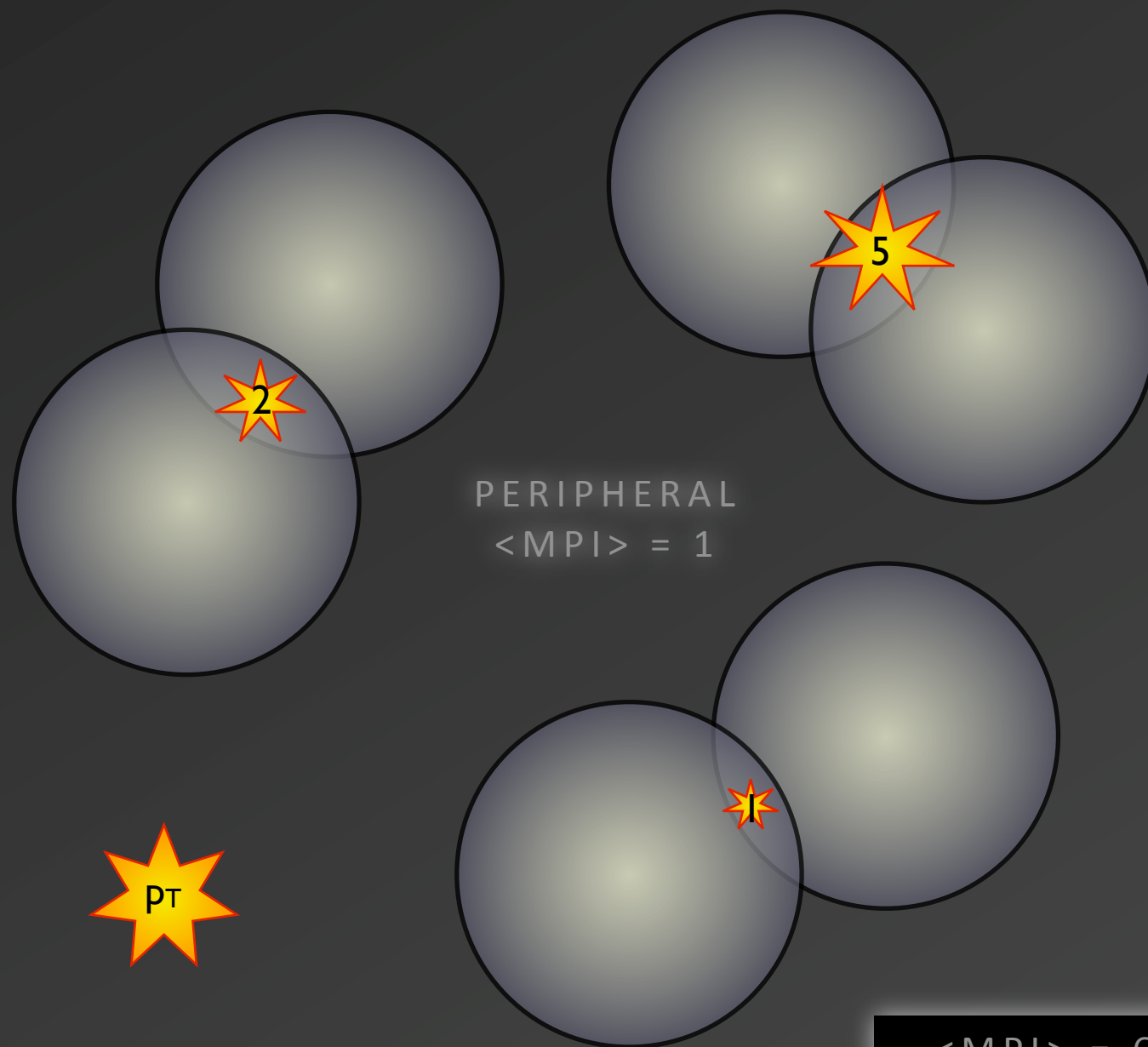


The Pedestal Effect

and Multiple Parton-Parton Interactions

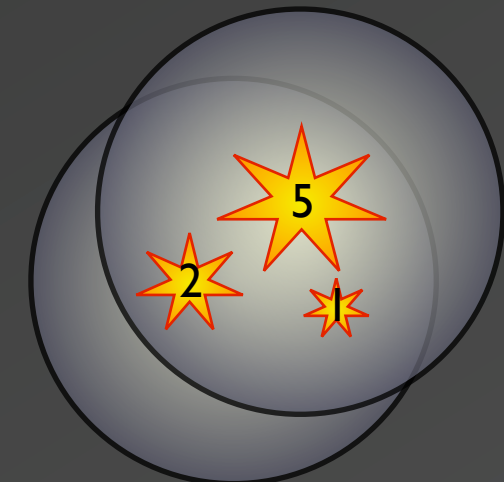
MINIMUM BIAS

$\sigma_{\text{parton-parton}}$
 $> \sigma_{\text{hadron-hadron}}$



+

CENTRAL
<MPI> = 3



$$\langle \text{MPI} \rangle = 6 / 4 = 1.5$$

The Pedestal Effect

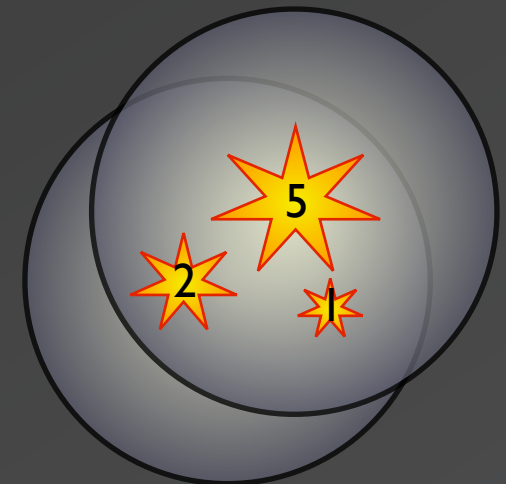
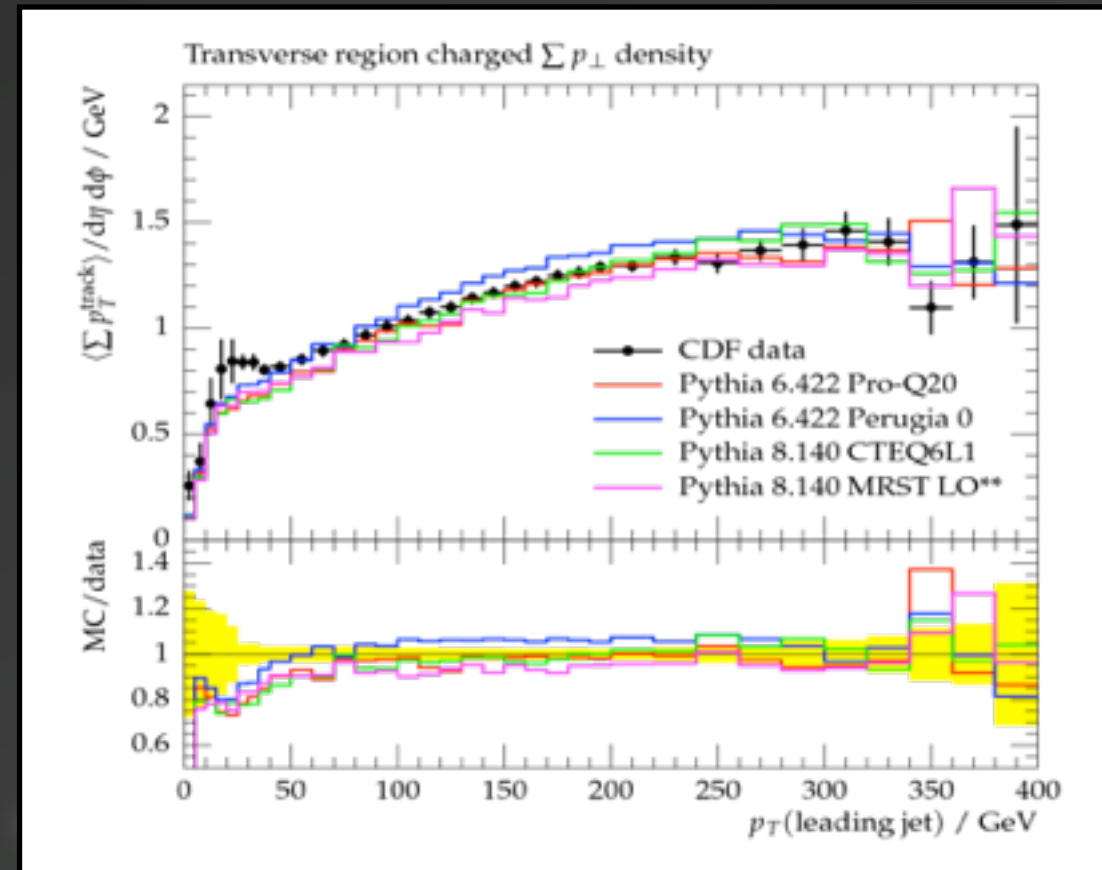
and Multiple Parton-Parton Interactions

JET > 5 GeV

Statistically biases
the selection towards
more central events
with more MPI

The assumed shape of the
proton affects the rise and
<UE>/<MB>

$$\langle \text{MPI} \rangle = 4 / 2 = 2$$



The Pedestal Effect

and Multiple Parton-Parton Interactions

JET > 5 GeV

Can we tell the difference?

Statistically biases
the selection towards
more central events
with more MPI

The assumed shape of the
proton affects the rise and
<UE>/<MB>

$$\langle \text{MPI} \rangle = 4 / 2 = 2$$

CENTRAL
<MPI> = 3

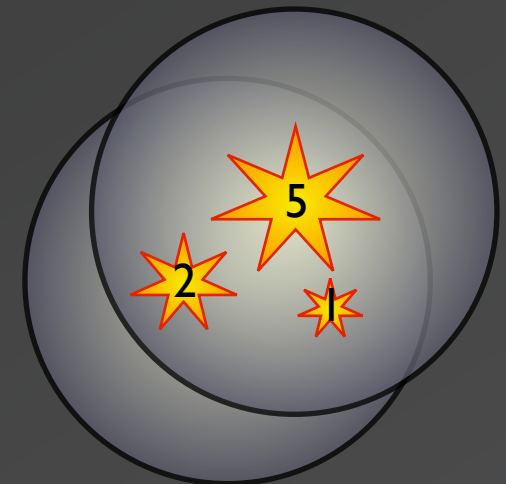
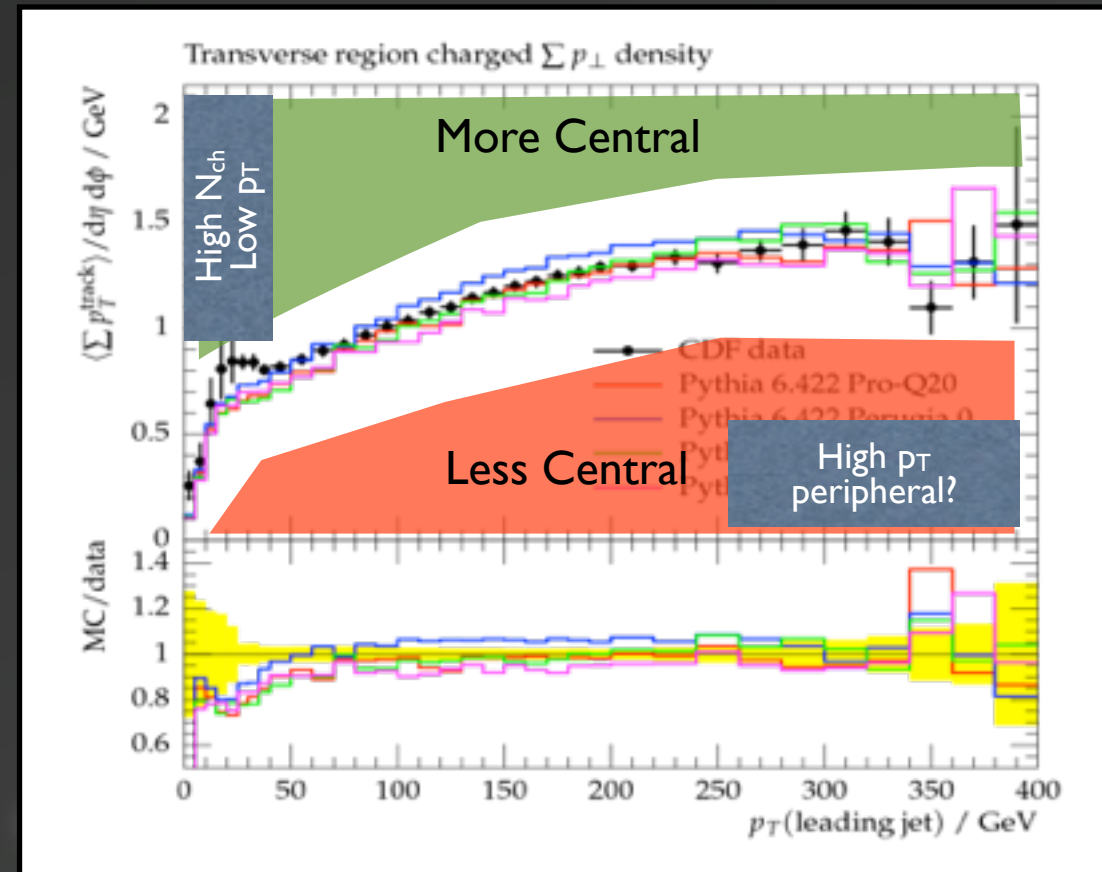
Dissecting the Pedestal

JET > 5 GeV

Statistically biases
the selection towards
more central events
with more MPI

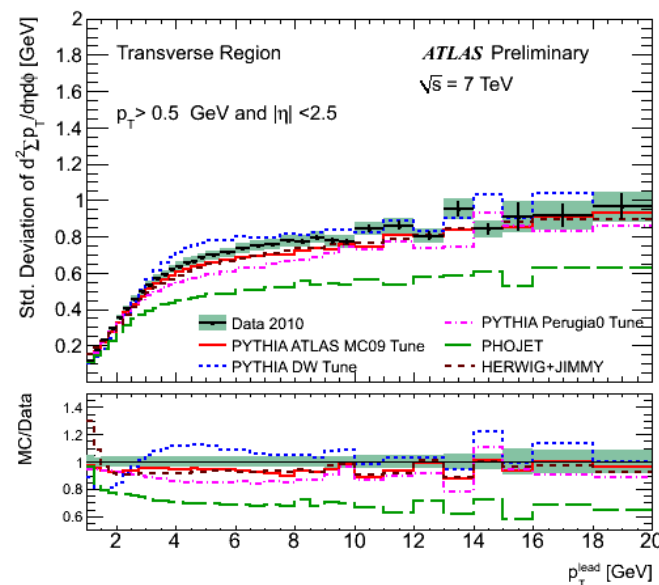
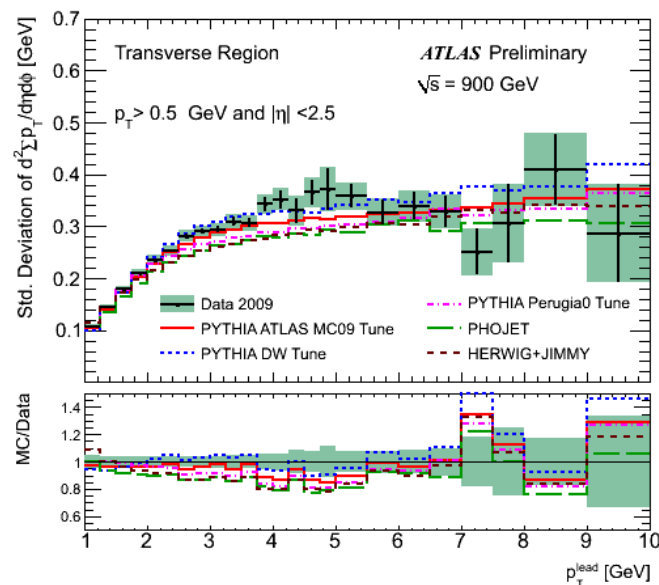
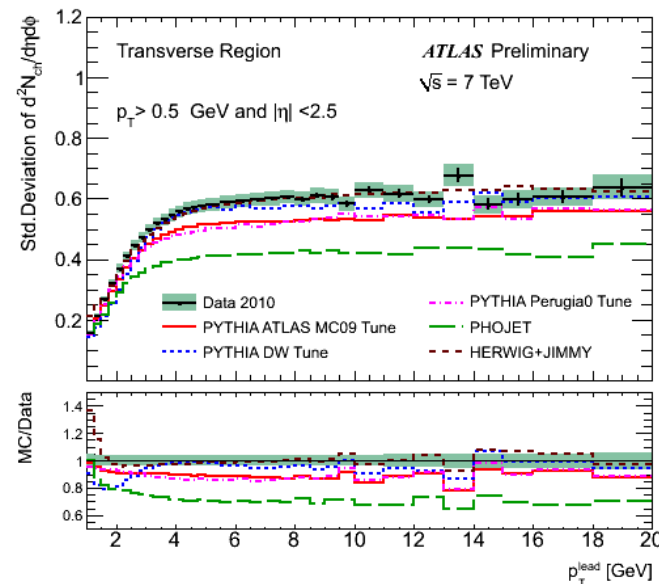
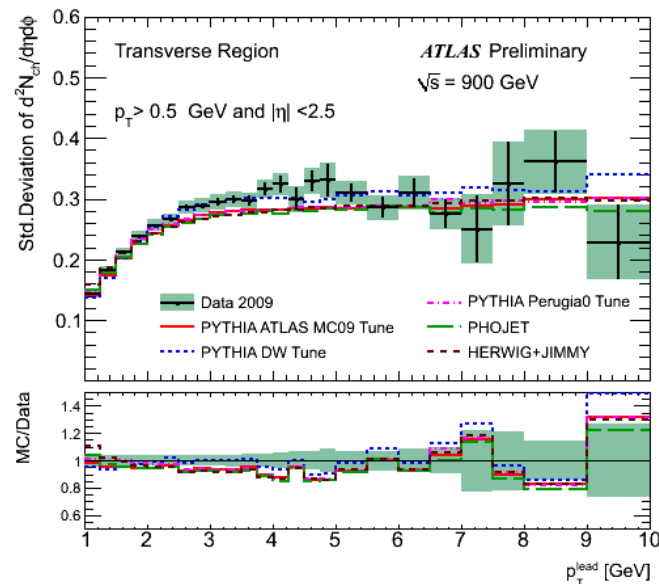
The assumed shape of the
proton affects the rise and
<UE>/<MB>

$$\langle \text{MPI} \rangle = 4 / 2 = 2$$



Possible to do at Tevatron?

Transverse Region Variances



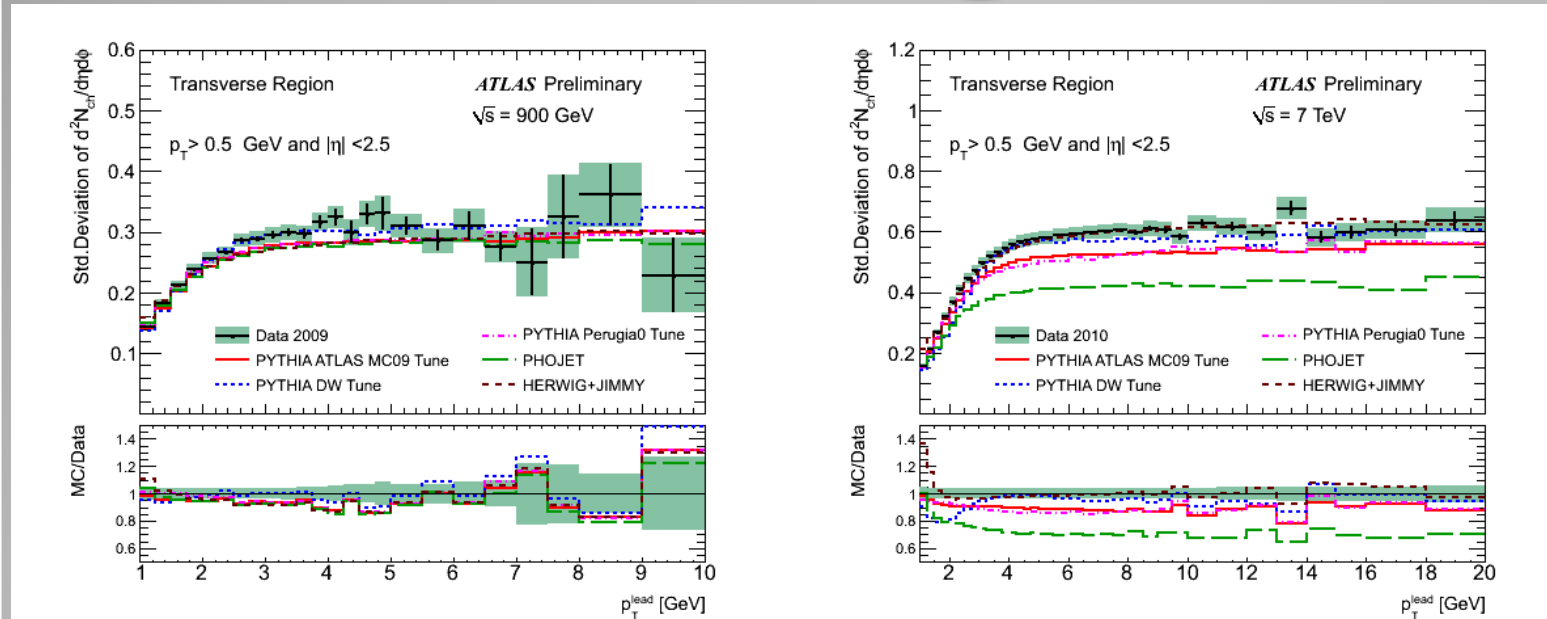
S.D. lower than mean, but more than square root of mean.

Suggests tracks not independently produced (not Poisson distribution).

S.D. provides a additional constraint on generator tunes

Possible to do at Tevatron?

Transverse Region Variances



S.D. lower than mean, but more than square root of mean.

Suggests tracks not independently

Analyzing the Pedestal?

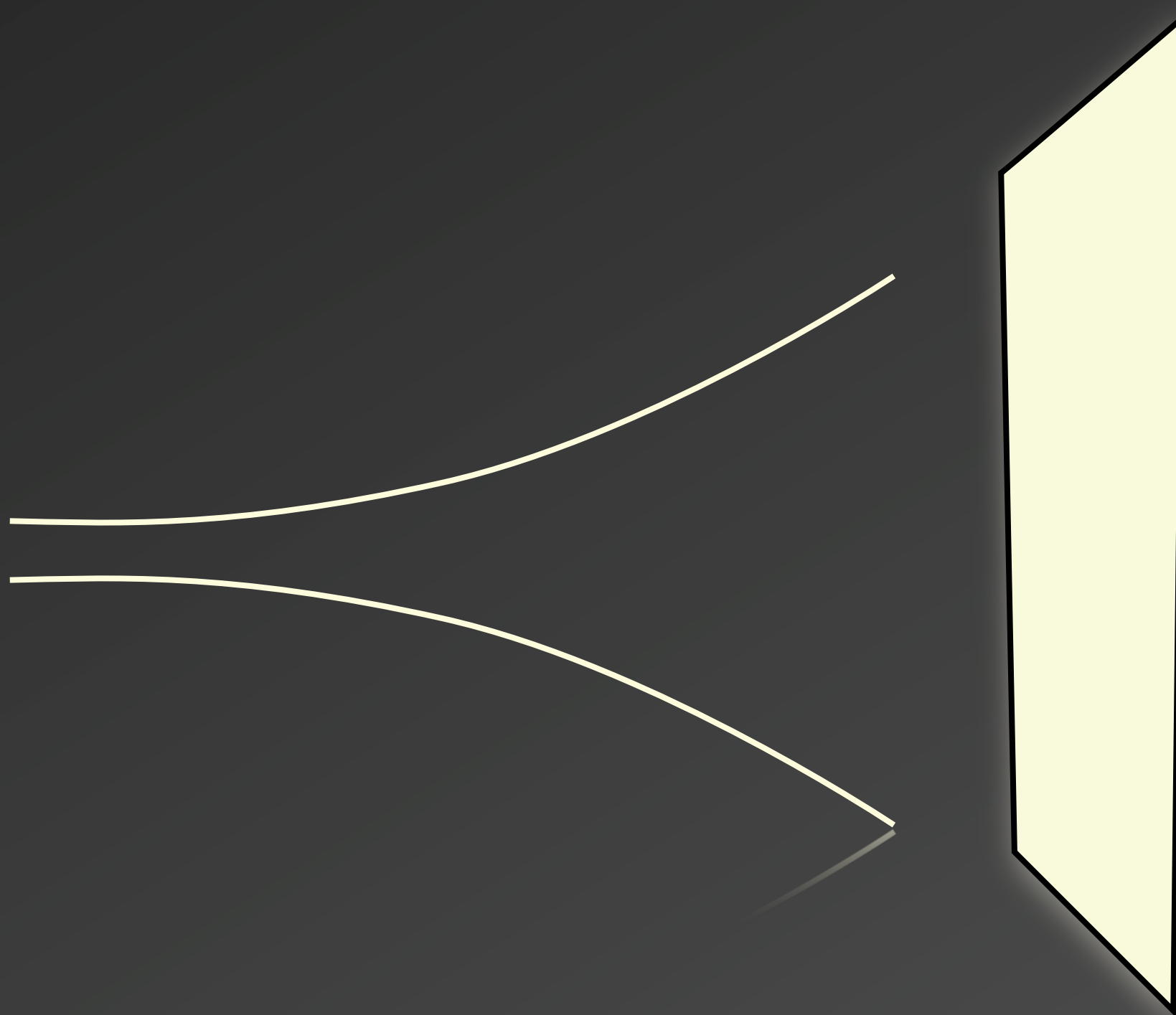
Initial rise & $\langle \text{UE} \rangle / \langle \text{MB} \rangle \rightarrow$ “average” proton shape

Focus on specific x range (pick jet p_T and y , for given collider energy)

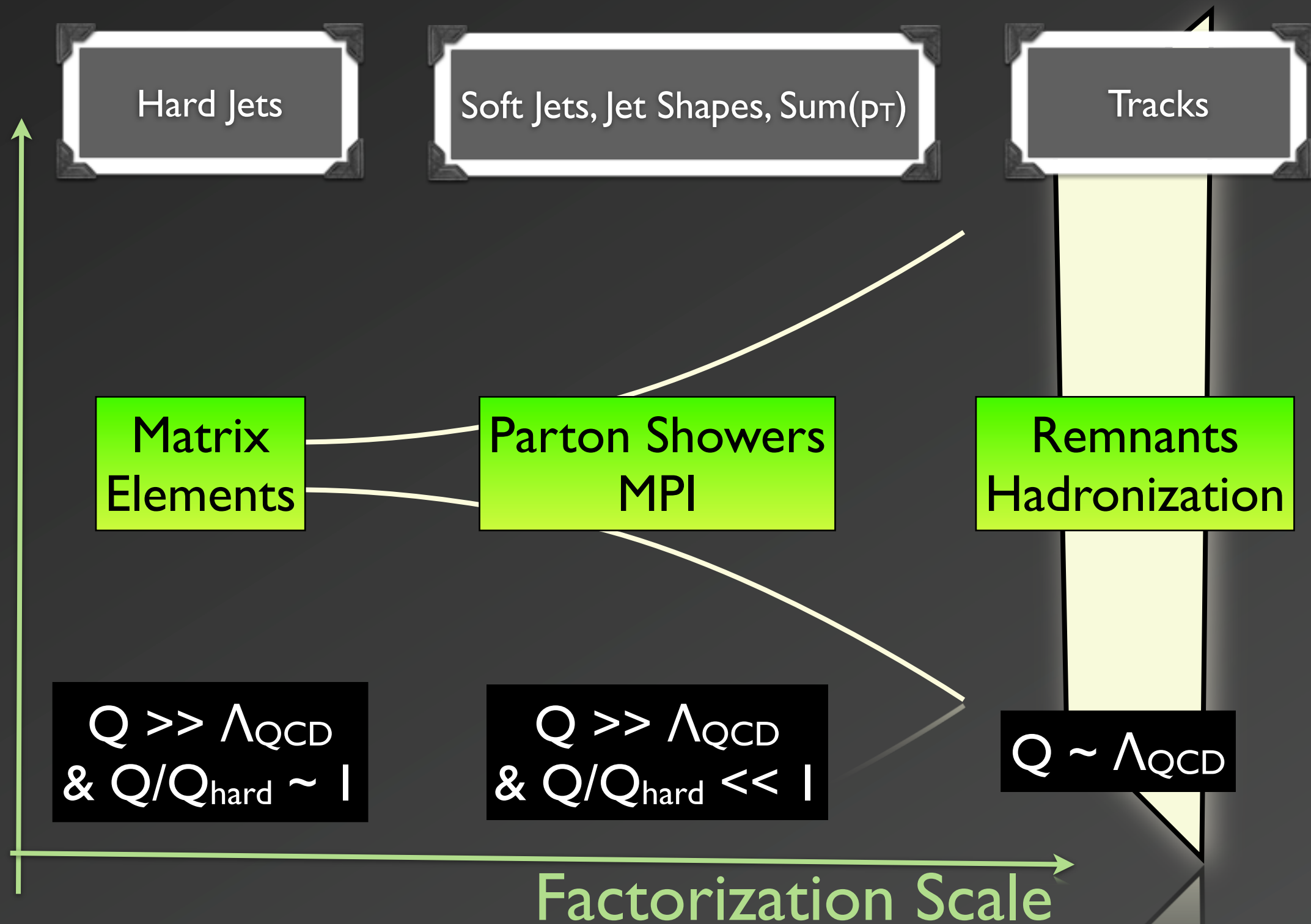
Scan over transverse activity $\rightarrow b$ dependence for that x ?

And/or look for abundance of minijets in transverse region

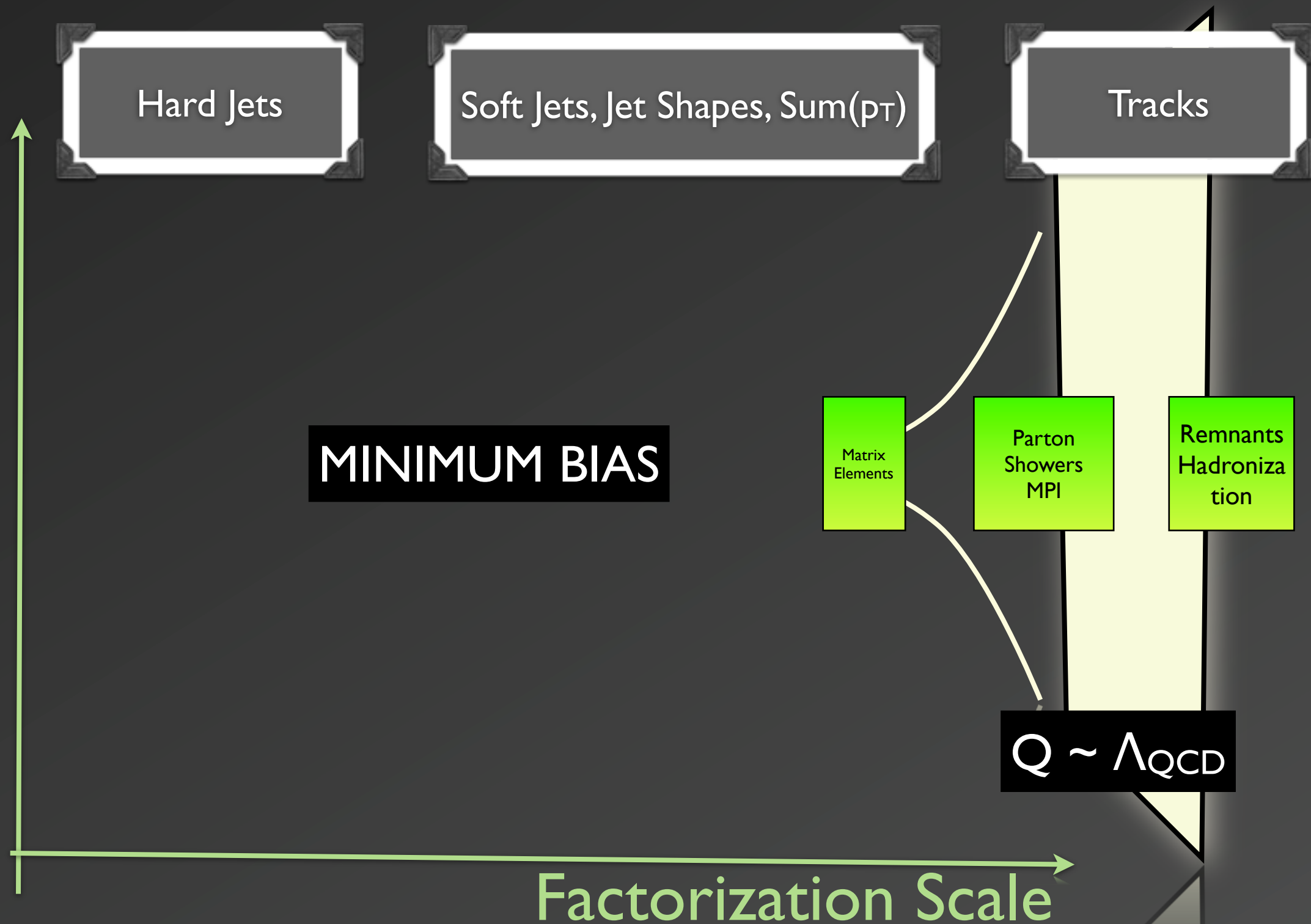
A New Look?



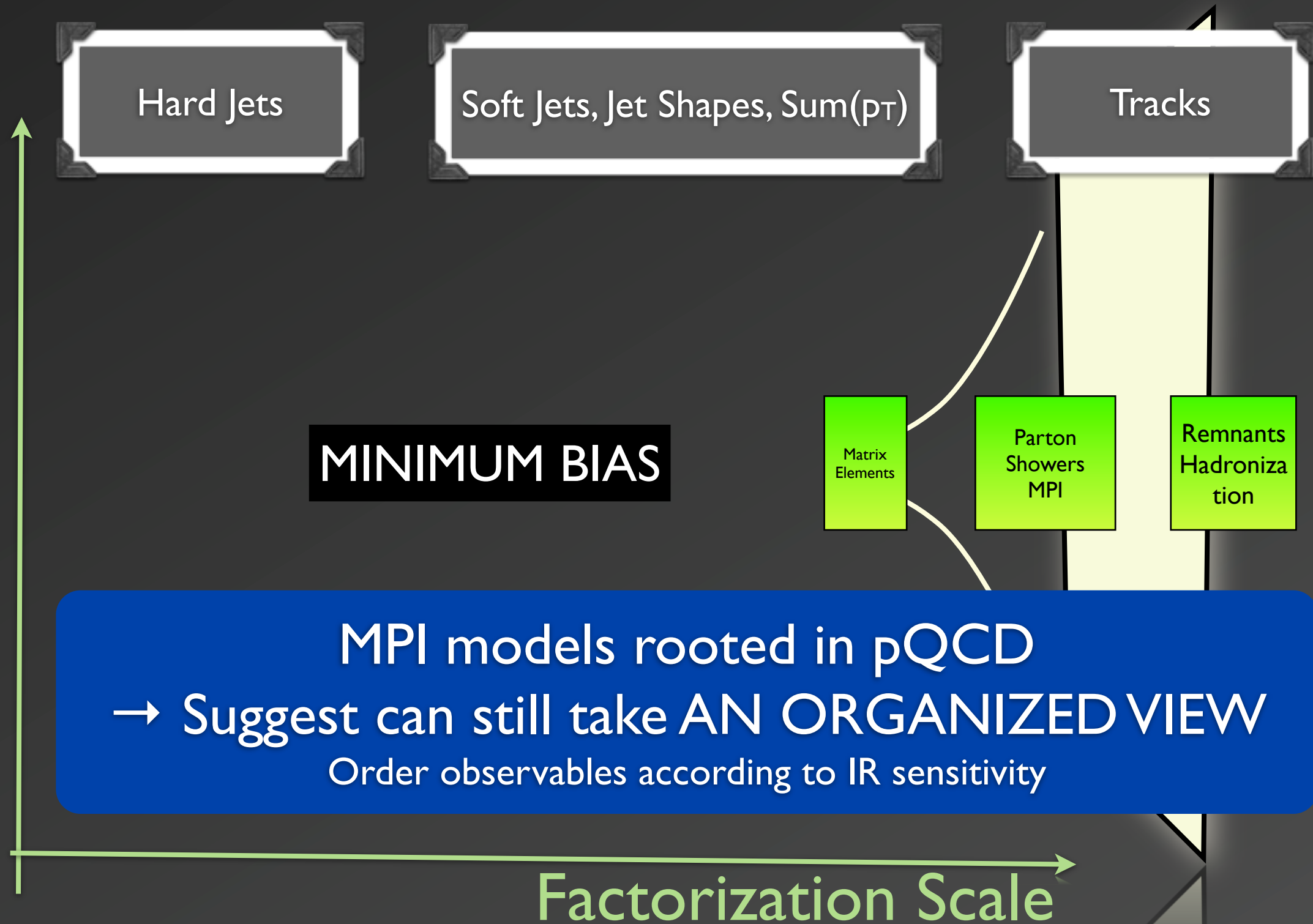
A New Look?



A New Look?



A New Look?



An Organized View

1. Where is the energy going?

Sum(p_T) densities, event shapes, mini-jet rates, energy flow correlations... \approx sensitive to $pQCD + pMPI$

2. How many tracks is it divided onto?

N_{tracks} , dN_{tracks}/dp_T , Associated track densities, track correlations... \approx sensitive to hadronization + soft MPI

3. What kind of tracks?

Strangeness per track, baryons per track, beam baryon asymmetry, ... s-baryons per s, multi-s states, s-sbar correlations, \approx sensitive to details of hadronization

IR Safe

IR Sensitive

More IR Sensitive



Organized Tuning

Can we be more general than this-tune-does-this, that-tune-does-that?

Yes

The new automated tuning tools can be used to generate unbiased optimizations for different observable regions

Same parameters → consistent model (not just “best tune”)

Critical for this task (take home message):

Need “comparable” observable sets for each region

Example: use different collider energies as our “regions” → test energy scaling
Other complementary data sets could be used to test other model aspects

Energy Scaling

“Energy Scaling of MB Tunes”, H. Schulz + PS, in preparation

Used CDF, UA5, and ATLAS data

$P(N_{ch}), dN_{ch}/dp_T, \langle p_T \rangle(N_{ch})$

Not $dN/d(\eta)$ to avoid emphasis on low mult

+ for ATLAS: can even focus on $N_{ch} \geq 6$ separately! Possible to do at Tevatron too?

From 630 GeV to 7 TeV

(Unfortunately, did not have a complete obs set from STAR at 200 GeV)

Reduce model to 3 main parameters:

Starting point = Perugia 0

1. Infrared Regularization Scale

p_{Tmin}

PARP(82)

2. Proton Transverse Mass Distributions

μ

PARP(83)

3. Strength of Color Reconnections

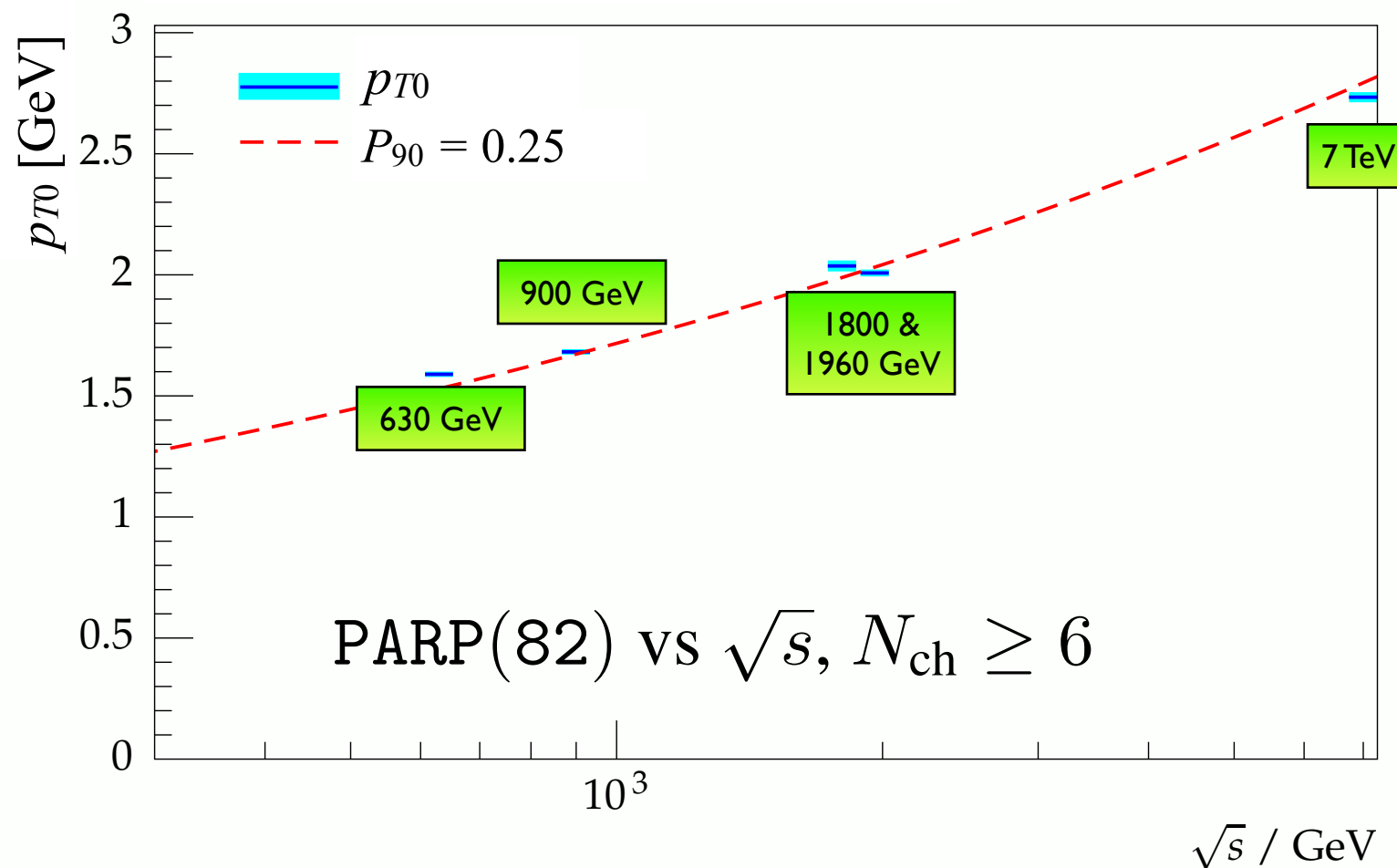
CR

PARP(78)

Use Professor to do independent optimizations at each energy

Infrared Regularization Scale

Model : $p_{\perp 0}^2(s) = p_{\perp 0}^2(s_{\text{ref}}) \left(\frac{s}{s_{\text{ref}}} \right)^{P_{90}}$ (power law)



cf., also, e.g., CMS, studies by R. Field

&

Sjöstrand & van Zijl, PRD36(1987)2019

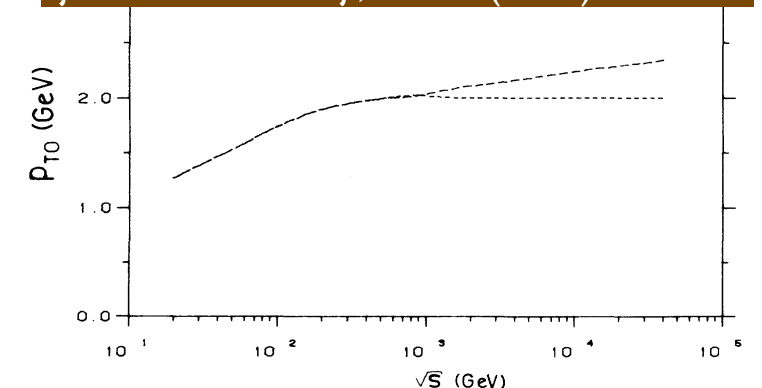


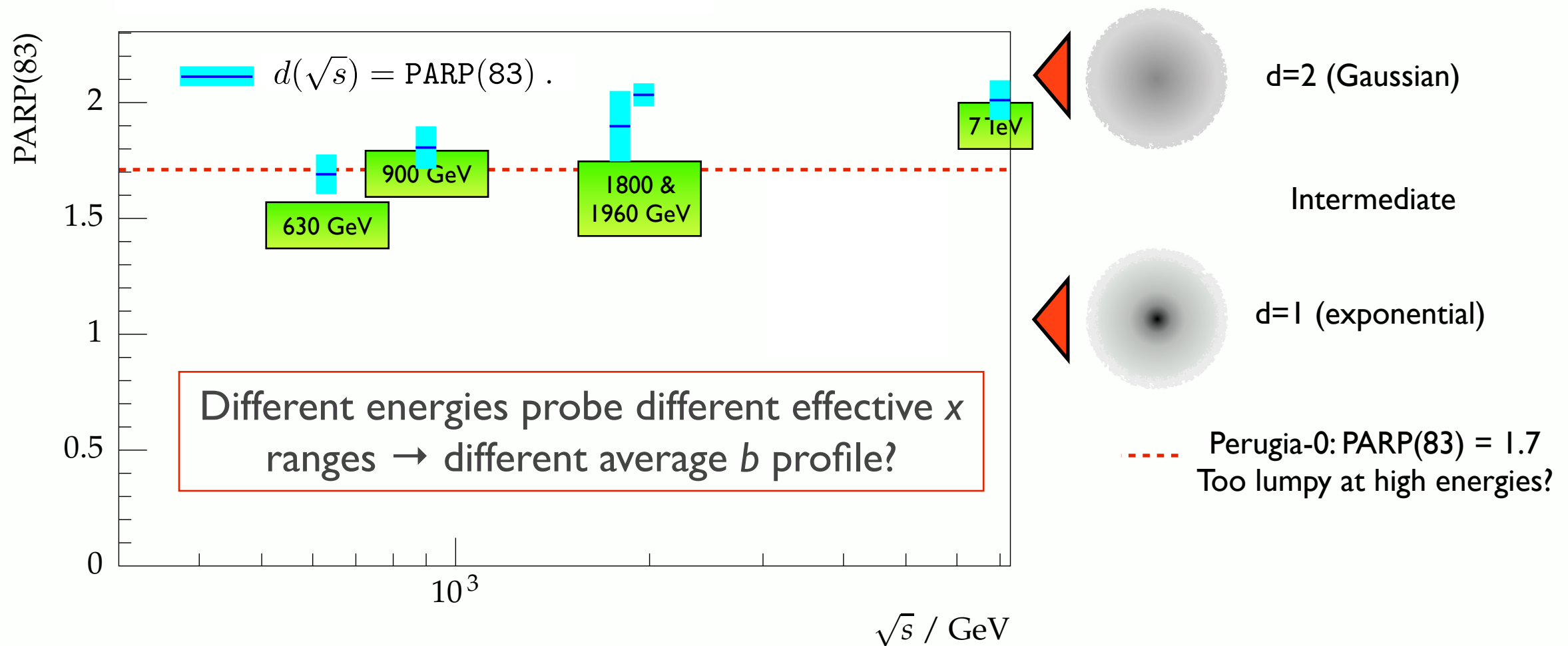
FIG. 8. Values for the cutoff parameter p_{T0} as a function of c.m. energy, as determined from comparisons with the average charged multiplicity. Dashed line, with a logarithmic extrapolation to higher energies, Eq. (38); dotted line, if assumed constant above 900 GeV.

No large deviation from the assumed functional form

(E.g., Tunes A, DW, Perugia-0 use $\text{Exp} = \text{PARP}(90) = 0.25$)

Transverse Mass Distribution

Model : $\mathcal{O}(b) \propto \exp(-b^d)$ (independent of energy)

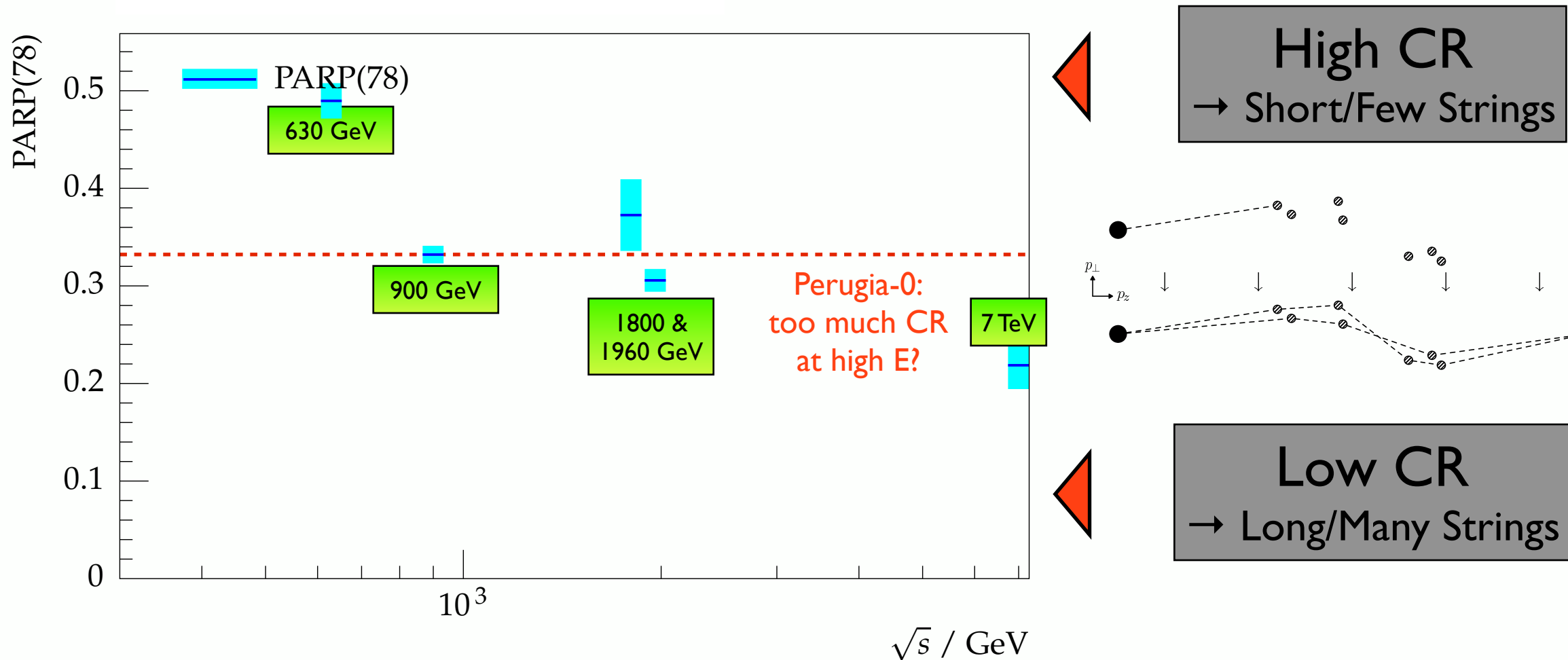


Hint of departure from Gaussian ($d=2$) at lower E_{cm} ?

Interesting to get more independent handles on b distribution
+ make more use of 200 and 630 GeV data ?

Color Reconnection Strength

Model : $P_{\text{keep}} = (1 - \zeta P_{78})^{n_{\text{int}}}$ (energy dependence implicit through $\langle n_{\text{int}} \rangle$)



Assumption of constant strength not supported by data!
Underscores the need for better physical understanding

Summary

The pedestal effect

Gives relation MB \rightarrow UE, driven by proton shape

Tevatron tunes generally low at 7 TeV

But 20% not spectacular; can probably do better, but

Advocate more systematic approach to tuning & testing:

Factorize: Order observables from IR safe to IR sensitive

Global View: test models on many obs, not just one (duh!)

Tuning Tools: can be used for more than tuning

PS: Perugia 7-TeV prediction still untested: $\langle N \rangle_{pT>0.5, |\eta|<2.5, N \geq 4} = 14.45 \pm 1.26$